In-field Measurement of Combustion Emissions from Solid Fuel Cookstoves

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INTRODUCTION

Solid fuel cookstoves have been used as primary energy sources for residential cooking and heating activites for ages, and the practice continues heavily, especially in developing countries. It has been estimated that domestic combustion of solid fuels (wood, animal dung, coal etc.) makes considerable contribution to global greenhouse gas (GHG) and aerosol emissions, degradation in local air quality, and deleterious effects on residents' health.

Accurate emissions from in situ solid fuel burning cookstoves have not been well characterized, and the maority of the data collected from simulated tests in laboratories does not reflect the stove performance in the field. This study characterizes in-field household emissions of $PM_{2.5}$, carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), and total non-methane hydrocarbons (TNMHC) from indoor cooking and heating events from a variety of solid fuels and stove types in different countries and regions which include Nepal, Mongolia, Tibet, India, and Yunnan province of China.

METHODS

SAMPLING METHODOLOGY

A sampling train is designed and built to achieve the comprehensive in-field measurement. The train includes in-line sampling filters and instruments to measure different parameters.

- Particle measurements
  - 37mm PTFE filter sample is collected for gravimetric analysis.
  - 47mm Quartz filter sampling for elemental carbon (EC) and organic carbon (OC) analysis.
  - DustTrak to monitor and log continuous real-time $PM_{2.5}$ concentrations (mg/m^3)

- Gas-phase measurements
  - Gas sample collected and analyzed for cumulative concentrations (ppm) of CO_2, CO, CH_4, & THC.
  - Q-Trak to monitor continuous real-time CO2 and CO concentration.

TABLE 1 Real-time measurement parameters

	INSTRUMENT	RANGE/ACCURACY	AVG. BATTERY LIFE	LOG INTERVAL
CO_2	TSI Q-Trak 7575/7565 Indoor Air Quality Monitor	0 - 5000 ppm ±3% / 50 ppm*	>12 hrs.	60 sec.
CO		0 - 500 ppm ±3% / 3 ppm*		
SO_2	Drager PAC 7000 Single Gas Monitor	0 - 100 ppm	> 1,000 hrs.	
$PM_{2.5}$	TSI DustTrak 8520 Aerosol Monitor	0.001 - 100 mg/m^3 (Particle size range: 0.1- ~10µm)	~12 hrs. w/external battery	

* Whichever is greater in value.

FIG 1. a Sampling train setup connected to a Tedlar gas sampling bag. b Interior view of emissions sampling train. c Sampling probe positioned above household stove emission.

METHODS (continued)

HOUSEHOLD SELECTION

The basis for the selection of participated households includes the ability to measure a variety of region-specific primary and secondary stove and fuel types. Depending on the site location, there were also constraints and considerations taken into account regarding household selection

TABLE 2 Overview of selected sampling site characteristics

LOCATION	DESCRIPTION	TEST #	HOUSEHOLD TYPE	STOVE TYPE	FUEL TYPE	PRIMARY ACTIVITY
NEPAL	Under-developed population, Limited electrical power supply	62	HOUSE	OPEN FIRE	WOOD DUNG AGRI RESIDUE	COOKING
TIBET_NAMCO	Extremely high elevation (4700m) and low ambient pressure (0.6 atm) Low population density Nomad lifestyle; popular tourism destination	21	TENT HOUSE	OPEN FIRE CHIMNEY	YAK DUNG	HEATING COOKING
TIBET_LINZHI	High elevation (3300m) Agriculture; tourism business	15	HOUSE	ADV_CHIMNEY	WOOD	COOKING
MONGOLIA	Extremely low ambient temperature (-40°C) High population density	157	GER HOUSE	CHIMNEY	COAL WOOD	HEATING COOKING
MEXICO		30	HOUSE	U TYPE PATSARI	WOOD	COOKING
INDIA	Similar with Nepal Higher population density	38	HOUSE	ANGITHI HARO CHULA IMPROVED	WOOD DUNG	COOKING
YUNNAN_FUYUAN	Well-developed village Electronic stove very popular Coal mine area	21	HOUSE	HIGH STOVE LOW STOVE PORTABLE STOVE	COAL WOOD AGRI RESIDUE	COOKING
YUNNAN_XUANWEI	Similar with FUYUAN High occurrences of lung cancer	21	HOUSE	HIGH STOVE LOW STOVE PORTABLE STOVE	COAL WOOD AGRI RESIDUE	COOKING

FIG 2. a Traditonal Tibaten tent. b Households and Gers in Mongolia. c Openfire stove and dung in Nepal. d Sampling from a high stove in Yunnan, China

PRELIMINARY RESULTS

TABLE 3 Summary of the result for MCE and emission factors (CO and $PM_{2.5}$)

| LOCATION	CHIMNEY	PRIMARY FUEL	SAMPLE #	MCE	EF CO [g/kg]	EF $PM_{2.5}$ [g/kg]
NEPAL	NO	WOOD	25	0.80± 0.03	227.33± 30.72	0.54±0.35
	NO	DUNG	20	0.79± 0.03	247.35± 38.37	2.51±1.88
	NO	AGRI RESIDUE	17	0.80± 0.03	235.92± 29.41	0.40±0.34
TIBET_NAMCO	YES	YAK DUNG	21	0.92± 0.03	137.32± 52.33	17.57±7.80
TIBET_LINZHI	YES	WOOD	15	0.89± 0.06	200.08± 94.91	24.66±11.56
MONGOLIA	YES	COAL	157	0.97± 0.002	64.50± 5.26	4.30±1.25
MEXICO	NO	WOOD	30	0.92± 0.02	283.24± 53.65	10.12±4.15
INDIA	NO	DUNG	20	0.90± 0.02	344.98± 70.26	24.94±8.34
	NO	WOOD	18	0.94± 0.02	211.93± 29.02	20.32±14.12
YUNNAN	YES	COAL	25	0.85± 0.02	254.49± 32.63	30.36±9.02
	NO	COAL	17	0.88± 0.02	211.16± 38.91	24.98±12.88
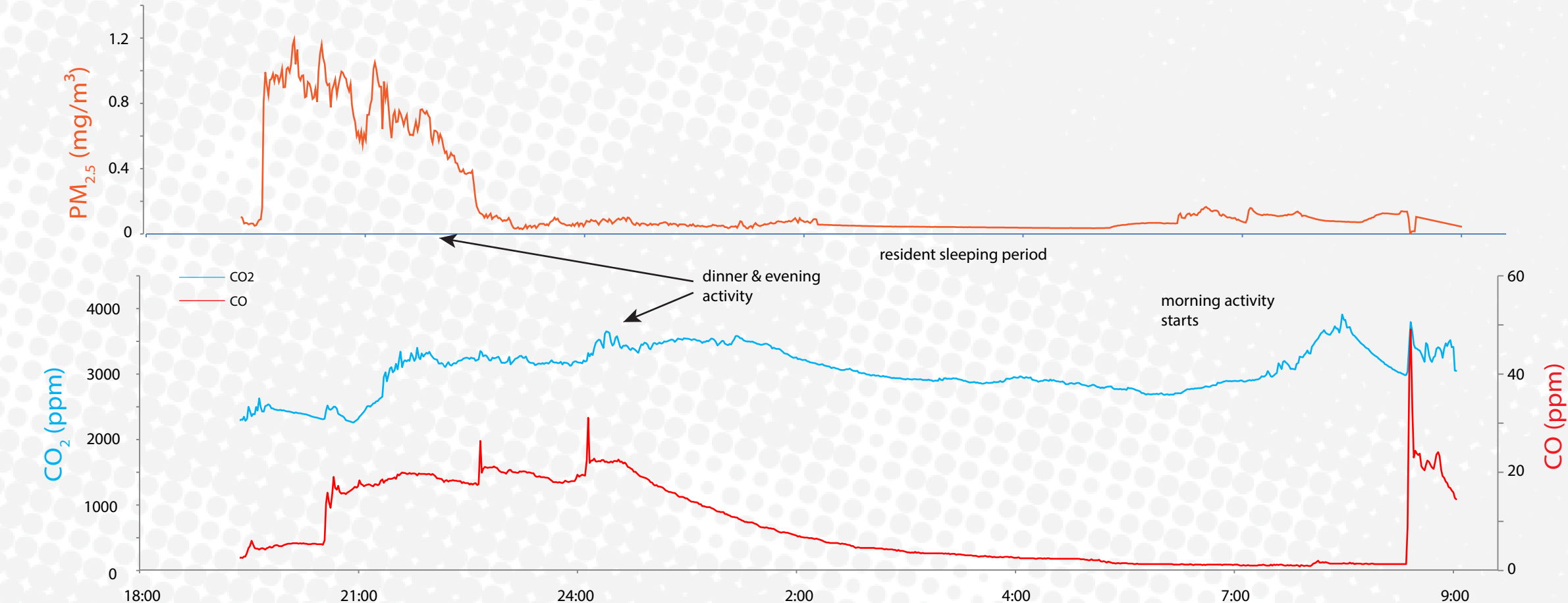
FIG 3. Example of typical background/indoor real-time gas and particle concentrations for a chimney stove in Ulaanbaatar, Monoglia.

CONCLUSION AND FUTURE PLAN

- A number of in-field measurements have been conducted, including several countries and Regions.
- Strong relation between primary fuel and emission is observed. Dung behaves as the dirtiest fuel in general.
- The stove activity has significant impact on the emission level (heating leads to higher efficiency compared with cooking).
- Complete and publish a comprehensive data set based on the results obtained from field sites.
- A quantified analysis for the effect of 'stove activity' will be investigated.
- Determine representative characteristics for estimating emissions from rural stoves.

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